Contributions to Geophysics and Geodesy Vol. 40/4, 2010 (323–350)

The estimation of errors in calculated terrain corrections in the Tatra Mountains

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Abstract: In general, calculation of terrain corrections can be a substantial source of errors in evaluating Bouguer anomalies, especially in rugged mountainous areas like the Tatra Mountains where we also get the largest values of the terrain corrections as such. It is then natural that analysis of their calculations in this area can shed light on the magnitude of correction-related errors within the whole Slovak territory. In the framework of our analysis we have estimated the effect of different computing approaches as well as the influence of accuracy of the inputs, i.e. the heights and positions of the measuring points, together with the used digital terrain models. For the sake of testing the computer programs which are currently in use, we have also substituted the real terrain by synthetic topography. We found that among the concerned constituents the most important factor is the used digital terrain model and its accuracy. The possible model-caused errors can exceed 10 mGal in the Tatra Mountains (for the density of 2.67 g.cm^{-3}).

Key words: terrain correction, digital terrain model, synthetic topography, Bouguer anomaly

1. Introduction

Traditionally, the correct evaluation of terrain corrections represents one of the most important steps in the process of Bouguer anomaly evaluation. The task of this paper is to answer the question of how large errors we can produce when calculating the terrain corrections in such a rugged topography like in the Tatra Mountains.

The Tatra Mts. area has been covered by gravity measurements that were realized within the frame of Czechoslovak state gravity mapping on the scale 1:25 000 which was performed mainly in the 1970's and 1980's. In general, the areal density of measuring points was 3-6 points per square kilometer. However, because of inaccessibility and strong roughness of the Tatra Mts. topography, it was not possible to determine properly the measured point heights, so here the mentioned areal density was not kept. It should be noted that optical leveling was practically the only method in use for acquiring accurate heights in those times.

These measurements were afterwards re-evaluated within the project "Atlas of geophysical maps and profiles" *(Grand et al., 2001).* The results of this project pointed out that the original terrain corrections were the most important contributor to the aggregate error in the Bouguer anomaly, mainly because they were calculated at least partly manually, without computers, what brought a subjective element to this process. *Grand et al. (2001)* re-calculated the terrain corrections in a modern way and evaluated their accuracy. However, these authors also highlighted the important fact, namely that the digital terrain model (DTM) they used for the nearest correction (T1) calculations was insufficient for that purpose. In relation to this issue they were reporting rather about estimation of T1 corrections than about their calculation.

Later on, joint gravity and modern geodetic measurements were realized in the year 2004, in cooperation between Geocomplex Inc. Bratislava and the Department of Theoretical Geodesy of the Slovak University of Technology, within the project "Gravity mapping of the Tatra Mountains" *(Panáček et al., 2005).* The task of this project was to enhance the covering of the Tatra Mts. by gravity measurements using modern methods of precise gravity and geodetic data acquisition by means of Scintrex CG-3 gravity meter and Trimble 5700 GPS receivers. The results were used to improve Bouguer anomaly map as well as the shape of quasigeoid in the Tatra Mts. area. Total number of measured points then was 152 with mean elevation 1923 m, while the highest point was 2631.5 m high (Fig. 1). The heights of the measuring points were derived on the base of combination of ellipsoidal heights (measured directly using GNSS technology) and the

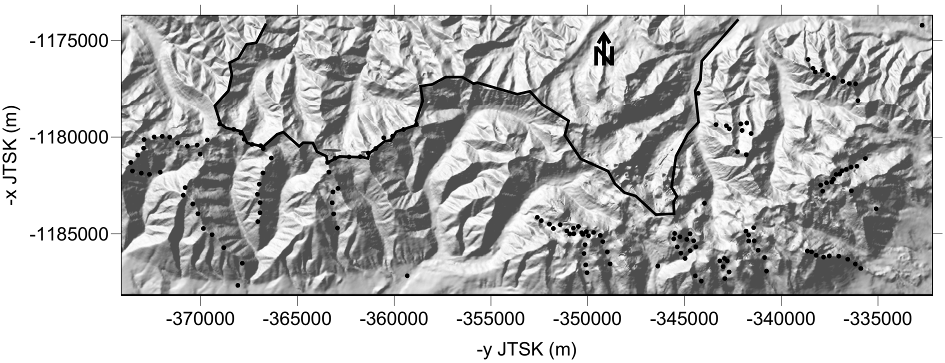

Fig. 1. Situation of the measured points within the project Gravity mapping of the Tatra Mountains. The black line represents the Slovak-Polish border.

Slovak National Quasigeoid DVRM *(Klobušiak et al., 2005; Mojzeš et al., 2006)*. The results of this project were later analyzed in *Janák et al. (2006)* and in *Szalaiová et al. (2006)*.

The measured values of gravity, as well as the positions and heights of the measuring points, form a very suitable set for calculating terrain corrections and examination of their properties in such a rugged topography. Having examined them, within this study, we found some interesting facts about our capability of calculating terrain corrections in mountainous areas.

2. Methods of accuracy evaluation

The terrain correction is defined as gravitational effect of topographic masses, which exceed or lack relative to the top of the truncated spherical layer up to the spherical distance of 166.7 km from the measuring point (e.g. *Hinze et al., 2005*). The effect of distant terrain beyond this range *(Mikuška et al., 2006)* is outside the scope of this paper.

Nowadays, terrain corrections calculation is performed using computational algorithms, while the position and elevation of calculating point as well as the DTM represent the inputs to the calculation. Calculation area around the calculating point is subdivided into several zones, whereas in each zone a different DTM is used, i.e., the closer to the point we are the more detailed terrain model we use. Dividing into four circular zones (grouping the zones of the original Hayford system), namely zone T1 up to 250 m from the calculating point (in the older approach of *Blížkovský et al. (1976)* a square zone was used; in the original Hayford system the closest radius was 230 m), zone T2 up to 5240 m, zone T31 up to 28 800 m and zone T32 up to 166.7 km, has been the most commonly used concept in the former Czechoslovak and recently also in the Slovak geophysics. On the other hand, there have been a variety of approaches to both sub-dividing of the calculation area within the individual zones and to the methods of the topography approximation. As well, there are several DTMs available in Slovakia, including the data accessible freely via internet (e.g. SRTM or ASTER). In this paper we use the term digital terrain model (DTM) for all models, although the term digital elevation model (DEM) would be more appropriate in some cases (ACE2, 2010; ASTER, 2010; SRTM, 2010).

In order to evaluate the accuracy of the terrain correction calculation, we must consider several factors, i.e., used computing program, accuracy of the input data (positions and heights of the calculating points) and accuracy of the used DTM. However, there is a problem, because we in fact do not have something like a standard or a calibration sample for the examination of our calculations in a real terrain. Therefore our method of evaluation was to compare several independent computing software modules and several input DTMs expecting to get an idea about the accuracy of the calculation as such. In the case of the non-DTM input data we were simply comparing the original outputs with those which were obtained when we added or subtracted some artificial errors to the positions as well as the heights of the calculating points. The detailed description and interpretation of our tests are given below.

It needs to be stressed that in such a rugged terrain like the Tatra Mts. we should expect the larger errors in the calculated terrain corrections in comparison with the rest of the territory of the Slovakia.

3. The comparison of calculating techniques

In general, if we want to compare different calculation techniques the requirement is to use identical DTM for a given zone in each case, i.e., we can compare only such programs that accept an identical DTM format.

For our test we used three calculating approaches, denoted A, B, C. Approach A (authors Grand and Pašteka) was used for the re-calculation of the terrain corrections of the gravity database within the project "Atlas of geophysical maps and profiles" *(Grand et al., 2001)*. The calculation of terrain correction is realized by summation of gravitational effects of vertical prisms (with triangular basis in the zone T1 and square basis in the other zones) with inclined or horizontal planar upper surfaces, which approximate the terrain model around the point of calculation. Further description is given in *Grand et al. (2004)*.

Approach B was represented by the program MassCorr (author Igor Cerovský), which calculates the so-called mass corrections. Here the gravitational effect of all masses above the sea level on the basis of the effect of polyhedrons is calculated, based on the formulas of *Pohánka (1988) (Cerovský, 2001)*. These mass corrections were later transformed into terrain corrections by the authors of this paper.

For the third approach (approach C) we have chosen an older program produced in the former company of Geofyzika Brno that was in use in Geocomplex Inc. when calculating the terrain corrections within the above mentioned project "Gravity mapping of the Tatra Mts." *(Panáček et al., 2005)*. This program uses vertical prisms and spherical segments (*Tomáš Grand*, personal communication).

We calculated all the terrain corrections for the density 2.67 g.cm^{-3}. Corrections T1 were calculated for interpolated heights of calculating points. These were obtained from the actual DTM by means of bi-linear interpolation in Surfer 8 *(Surfer, 2010)*, while the other corrections (T2, T31 and T32) were calculated for measured heights. We also note that the concept of interpolated heights was used during the re-evaluation of the Slovak gravimetric database *(Grand et al., 2001)*. The reason why we here also used interpolated heights in the case of T1 was that there are sometimes very large differences between the measured and interpolated heights in rugged terrains like the Tatra Mts. (even more than ± 200 m) and this could lead to incorrect outputs. We are aware of this problematic point and will make a short commentary on it later in the text. Actually this topic would need a deeper study, which is planned by the authors in the near future.

On one hand, the selected calculation programs accept various formats of DTM, but, on the other hand, we maintained the using of only identical DTMs for all programs. Here it needs to be reminded that we were keeping unified grid cell sizes for all used DTMs, namely 20×20 m for T1, 50×50 m for T2, 250×250 m for T31 and 1000×1000 m for T32 corrections.

For the comparison of various calculation approaches we have chosen the DTM, which had been used within the above mentioned project "Atlas of geophysical maps and profiles". Programs A and B are fully compatible, which means that they calculate terrain corrections in the identical zones with identical DTM so that the results could be readily compared. The comparison with approach C was somewhat complicated, because this program uses only square-bounded zone T1. This permitted the comparison only with the approach A, which is capable of calculating with both types of T1 zone boundary (i.e. circular or squared).

Table 1 presents the mean values of calculated terrain corrections for all 152 points for circular boundary between T1 and T2 zone. In the last column, T stands for the total corrections, for which the minimum, maximum and mean were independently determined. In Fig. 2 the histogram of their distribution is displayed.

Table 1. The elementary statistics of the calculated terrain corrections (2.67 g.cm^{-3}). Used inputs and methods: DTM ATLAS, calculation approaches A, B and C, interpolated height of the calculation point within T1 zone, measured height within the other zones

Terrain corrections	T1 (mGal)	T2 (mGal)	T31 (mGal)	T32 (mGal)	T (mGal)
Minimum	0.061	1.528	1.251	0.778	3.655
Maximum	7.625	48.673	20.716	8.910	85.744
Mean	1.637	11.958	6.689	4.494	24.731

In Fig. 3 and Fig. 4 we present statistics of the differences in the calculated terrain corrections for the selected programs in particular zones (for the density 2.67 g.cm^{-3}). We compare the approach A with the approach B (for circular T1 zone) and the approach A with the approach C (for square T1 zone). One can see that we get the greatest differences between the programs A and C for the terrain corrections T2, which is obviously a consequence of the fact that T2s have the highest values among all the components T1 to T32, see Table 1. In contrast, the differences in the T31 and

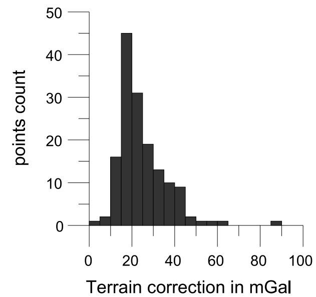

Fig. 2. Distribution histogram of the mean total terrain corrections T (152 points). See also the last column of Table 1.

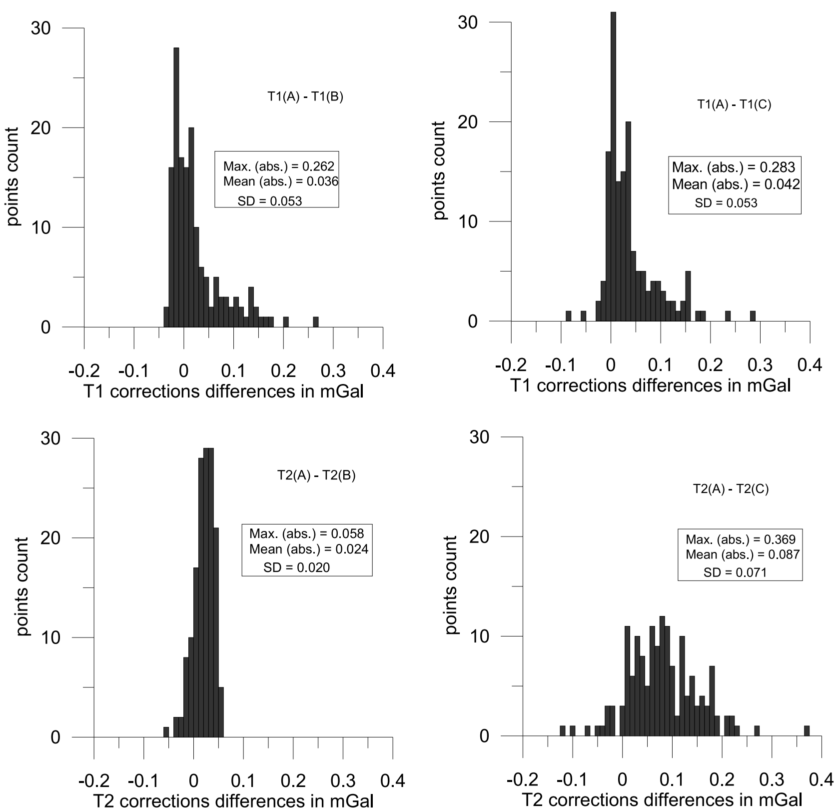

Fig. 3. The comparison of the terrain corrections T1 and T2 calculated using various programs A, B and C (152 points). Used inputs and methods: DTM ATLAS, interpolated height of the calculation point within T1 zone, measured height within T2 zone.

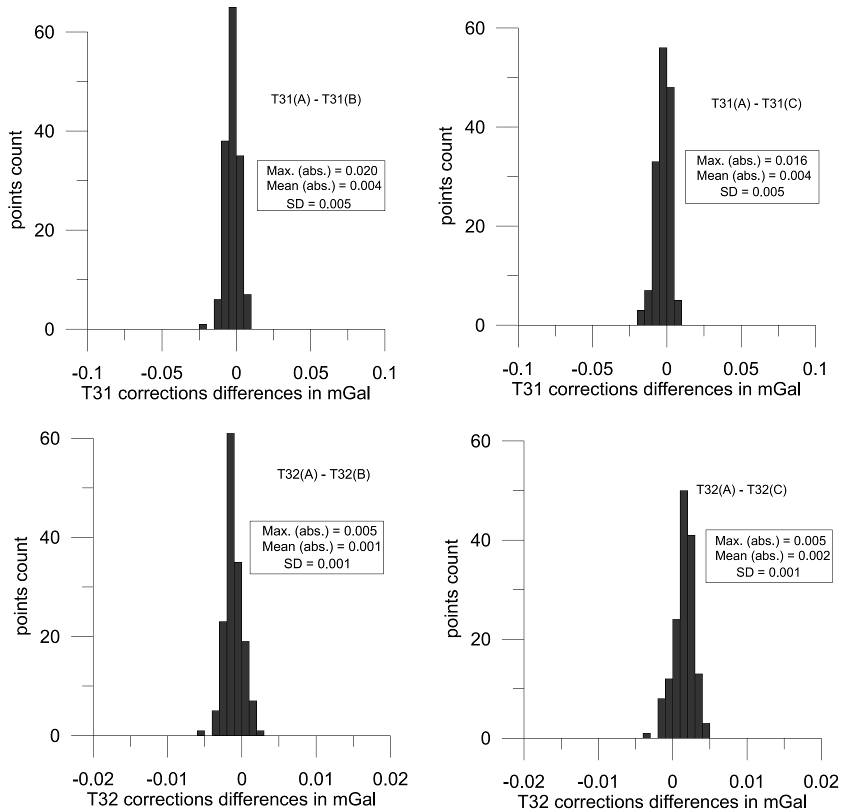

Fig. 4. The comparison of the terrain corrections T31 and T32 calculated using various programs A, B and C (152 points). Used inputs and methods: DTM ATLAS, measured height of the calculation point.

T32 corrections, respectively, are almost negligible (their mean differences are less than 0.005 mGal).

If we compare only the approaches A and B, which are the newest ones and are fully compatible, we get the greatest differences in the nearest zone, T1. If we take the absolute differences of T values (here we mean the sums for all zones, which are not shown in Figs. 3 and 4), we get the maximum value of about 0.29 mGal (mean value is about 0.07 mGal). We deem that these figures represent a plausible approximation of the maximum absolute error, which can characterize the accuracy of the terrain correction calculation in such mountainous areas from the aspect of the available software. On one hand, it is not a negligible value, but, on the other hand, we should note that the maximum value of the total terrain corrections themselves is more than 80 mGal (Table 1), so the estimated error is still less than 0.4 percent of this value.

We also performed another simple test to check the accuracy of the used calculating programs. We substituted the nearest zone around a calculating point by a synthetic topography model formed by a simple paraboloid and conus, respectively (Fig. 5), with the radius which was identical with the one of the T1 zone (250 m), while calculating point was situated at their apices. We then calculated the gravitational effect of such simple bodies using available closed formulas (e.g. *Válek, 1969*). After subtracting this value from the attraction of a planar circular plate (e.g. *Hammer, 1939; Vyskočil, 1960*) of the same height and radius, we get an accurate value for the T1 terrain correction (the earth curvature is neglected in this zone). Within such a test we can also estimate the influence of the grid cell size of the input DTM on the accuracy of T1 corrections. The comparison of the analytic values with the terrain correction T1 calculated using approaches A and B (for 2.67 g.cm^{-3}), in dependence on the adopted synthetic DTM grid cell size, is shown in Fig. 6. These calculations were made for the height of conus (paraboloid) equal to 250 meters; for lower bodies we get smaller differences. As we can see, the standard grid cell size of 20 meters produces differences which are close to 2 percent of the corresponding T1 values within this test; while in the case of real data these differences were

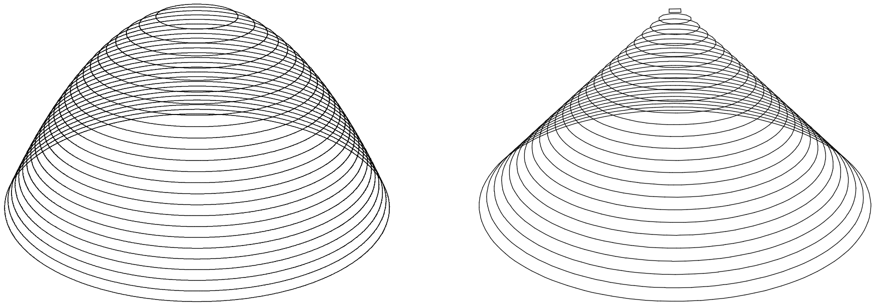

Fig. 5. Synthetic topography modeled by paraboloid and conus. Radii of their circular bases 250 m, heights to the bodies 250 m, calculation points situated at their apices.

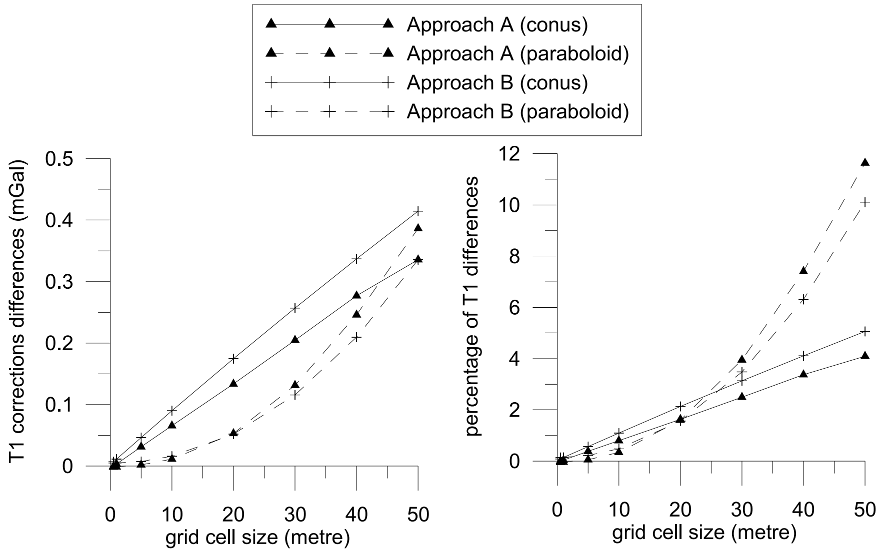

Fig. 6. The comparison of the T1 corrections calculated on simple synthetic models displayed in Fig. 5.

about 3 percent in average in the T1 zone. On the other hand, in the case of smaller grid cell sizes, both approaches give very accurate results. This represents an evidence of correctness of the used computing programs. Of course, we are aware of the fact that the real topography can be much more complicated in comparison with our synthetic models; therefore we consider the results of this test carefully.

4. The influence of inaccuracy of the input data

The input data for calculation of terrain corrections (in addition to DTM) are the heights and the positions of the measuring points. Thanks to the modern GPS techniques, nowadays we are capable of acquiring these data with quite a high accuracy (except deep valleys or forest-covered regions), so that we do not expect the height-related inaccuracy to produce great differences in terrain corrections. If we take the upper limit of the inaccuracy of measured heights in the gravity surveys in the Tatra Mts. ±0.15 m

(Panáček et al., 2005), we can simply estimate its influence on the terrain corrections in such a way that we change systematically the heights of measuring points plus or minus this value and recalculate terrain corrections (we did not use interpolated heights for T1 in this case). In this test we exploited more detailed DTM (DTM DETAIL, its description is given below) as was the previous one. For the considered height error of ± 0.15 m, we get maximum difference 0.027 mGal (for the density 2.67 g.cm^{-3}) in T1 corrections and 0.016 mGal in T2. In the case of T31 and T32 corrections, the differences are much smaller and can be regarded as negligible in such terrain conditions.

However, the inaccuracy of ± 0.15 m in the measured heights is considered under favorable field conditions, which are not always prevailing. For example, if we consider a hypothetical height error ± 1 m (e.g. in the case of some points situated in deep valleys), we get maximum differences 0.195 mGal (for the density 2.67 g.cm^{-3}) for T1 corrections and 0.107 mGal for T2 corrections, while the differences for the farther zones are still negligible. These differences are of the same order as the ones of the previous test in which we were using various computing approaches.

Concerning the accuracy of the horizontal position, if we consider equal error ± 0.15 m, we get very small differences in the terrain corrections (similar to those due to the same height error). However, we have to notice possible errors resulting from the coordinate transformations using various software modules, which also could represent a potential source of inaccuracy in horizontal position. When we assumed such an error of, for example, ± 2 meters, we obtained maximum error of about 0.28 mGal for T1 corrections (for the interpolated heights) and 0.06 mGal for T2 corrections.

5. The influence of the DTM inaccuracy

We have used several different DTMs for our tests. The first one (ATLAS) is the model of Slovakia, compiled within the project "Atlas of geophysical maps and profiles" *(Grand et al., 2001)*. It was created on the basis of DTM of Slovakia on the scale 1:50 000 (Geodetic and Cartographic Institute Bratislava, in *Grand et al., 2001*), which was corrected and supplemented using the digitized area surrounding the country territory and the GTOPO30 data *(GTOPO30, 2010)*.

Second DTM (DETAIL) is a more detailed terrain model of the Tatra Mts. area, which we used within another project *(Panáček et al., 2005)*. This model was compiled within the project CERGOP-2/Environment *(Czarnecki and Mojzeš, 2006)*.

Subsequently, we have derived terrain models from available internet data sets acquired by the InSAR technology (Interferometric Synthetic Aperture Radar). We have used three different sources of data, namely SRTM - Shuttle Radar Topography Mission *(SRTM, 2010)*, ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer *(ASTER, 2010)* and ACE 2 - Altimeter Corrected Elevations *(ACE2, 2010)*. The SRTM data are available with standard resolution 3×3 seconds in the latest improved version SRTM-3 v 4.1 *(CGIAR-CSI SRTM, 2010)* and in the nearby area of the Tatra Mts. they are available with resolution 1×1 second *(DED, 2010)*. The ASTER data have the resolution 1×1 second, but this first release is characterized as an experimental version *(ASTER GDEM, 2010)*. The ACE 2 Global Digital Elevation Model is derived from SRTM data by combination with altimetry *(Smith and Berry, 2010)*. It is available at 3-seconds resolution.

There are great differences between selected DTMs, mainly in the border area between Poland and Slovakia. When we compare these models in detail, especially the DTM ATLAS shows height differences up to 800 m in comparison with other models.

We can assess the accuracy of the used DTMs partially on the basis of comparison between the measured heights of our gravity points and the interpolated heights from the given DTM. The results of such evaluation are depicted in Fig. 7. The necessary interpolation is made by the software Surfer 8 using bi-linear method from the nearest grid points *(Surfer, 2010)*. This comparison indicates that the model ATLAS is the least accurate and the model DETAIL is the most accurate. The SRTM model (especially at 1 second resolution) appears to be better than the ASTER or ACE 2 ones in this area.

The discrepancies among terrain models used are logically reflected in differences among the calculated terrain corrections. In Fig. 8a and b, 9, 10, 11 there are shown statistical characteristics of the differences in corresponding terrain corrections, calculated using the approach B for the density

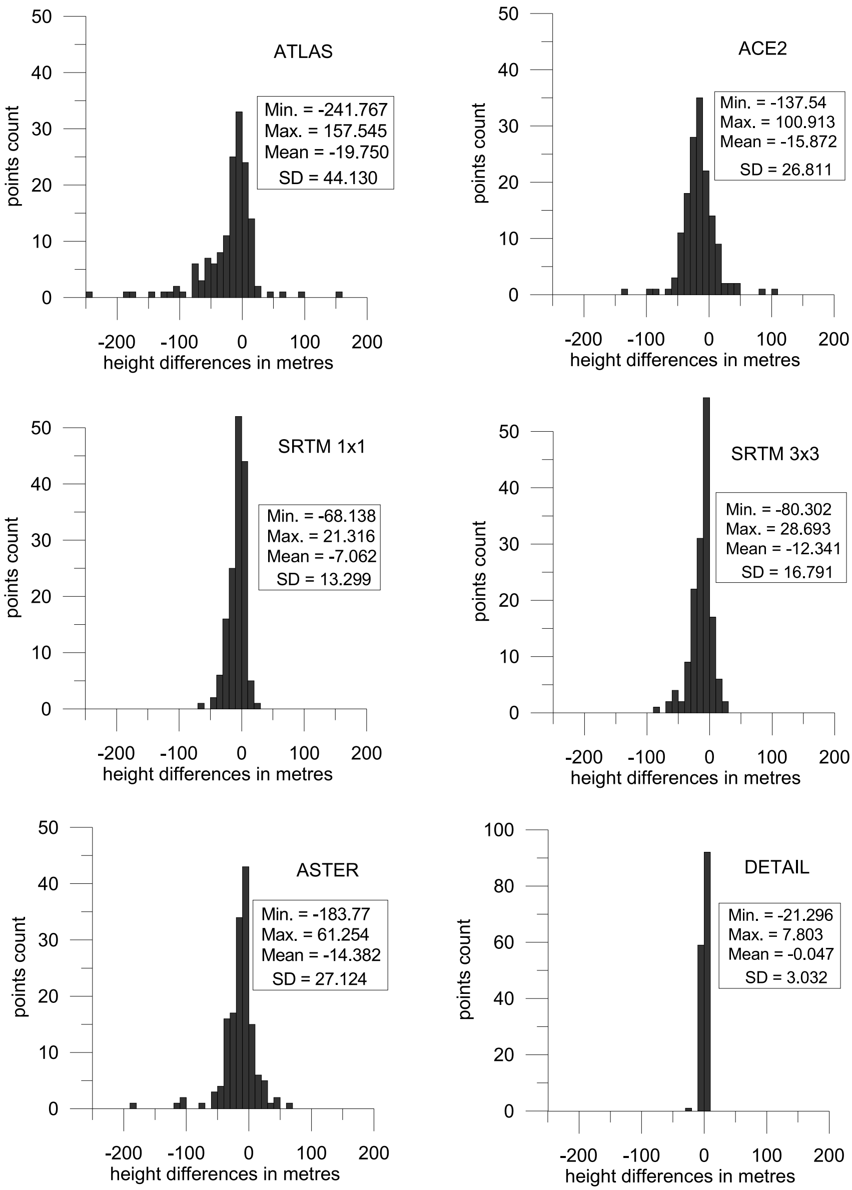

Fig. 7. The comparison of the measured and interpolated heights of the measured points from various DTMs (152 points). Note different vertical scale in the last graph.

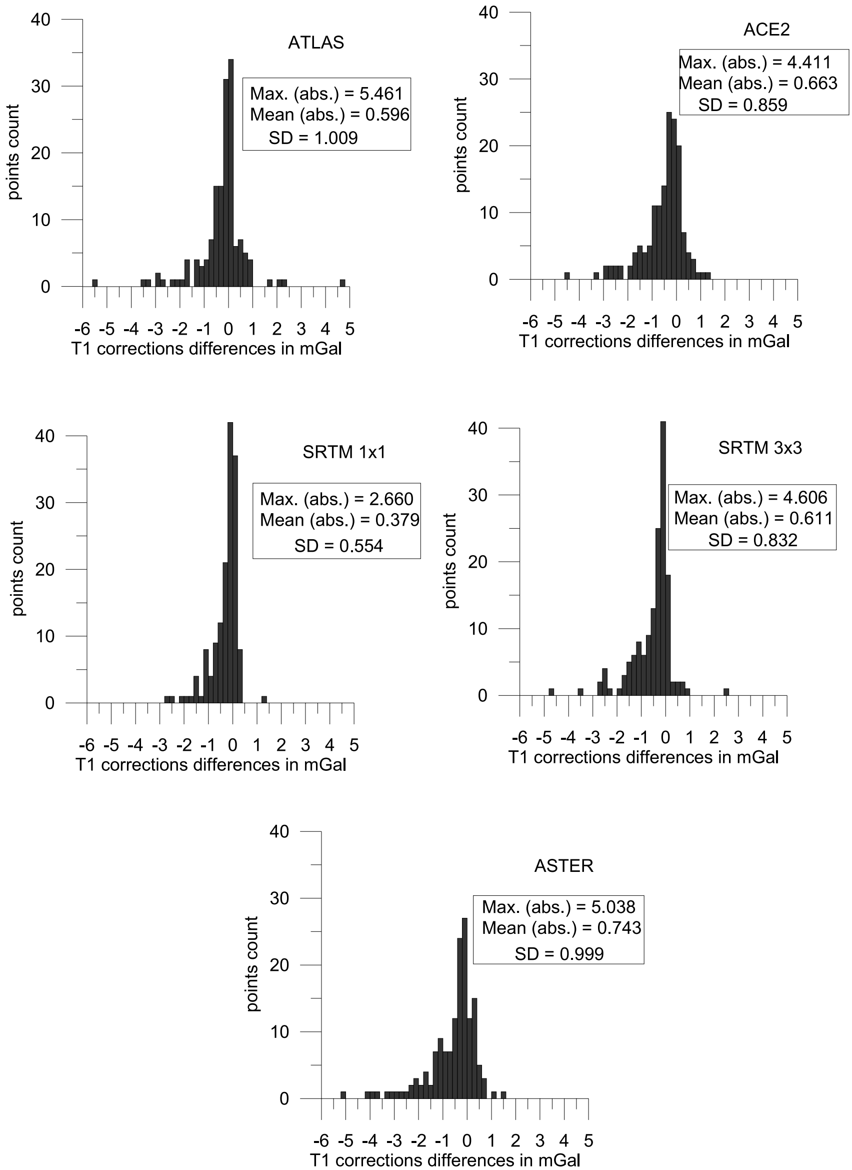

Fig. 8a. The comparison of T1 corrections (for interpolated heights) for the 152 points, calculated for various DTMs against the ones calculated for the DTM DETAIL.

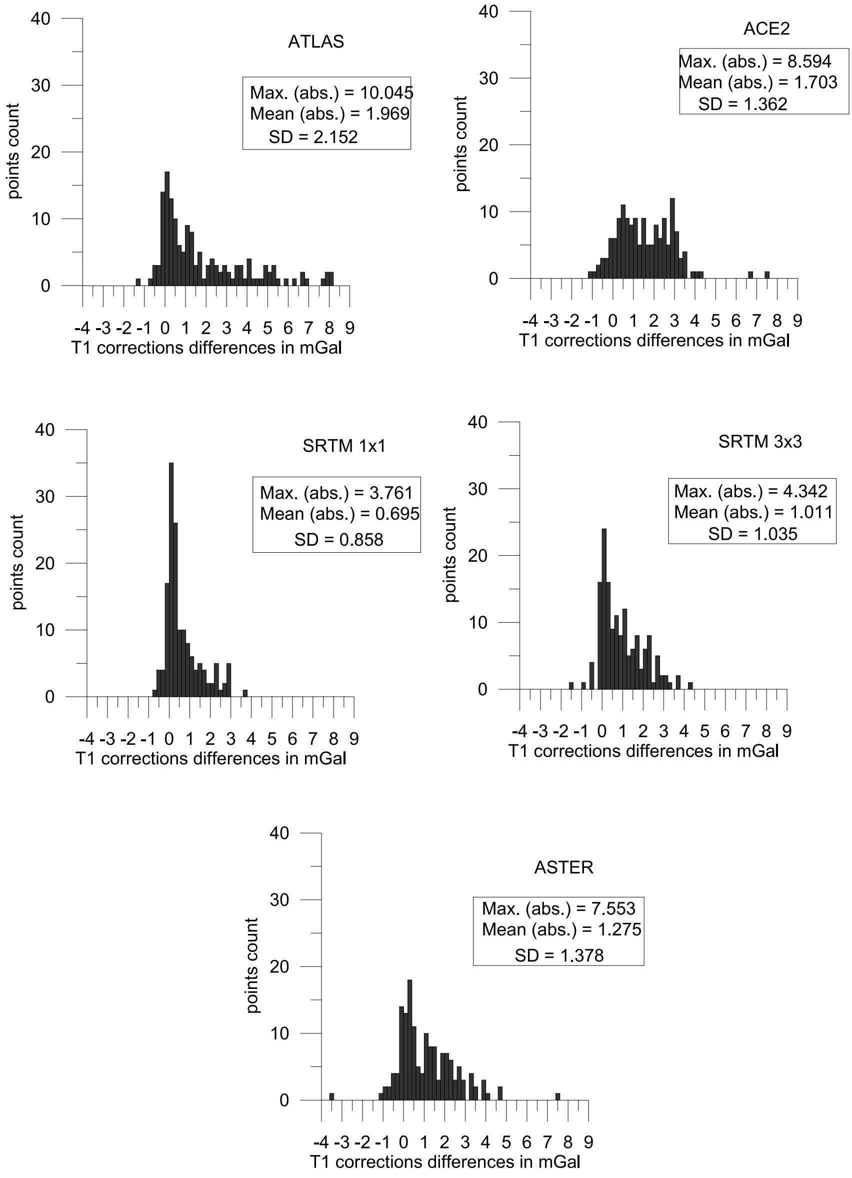

Fig. 8b. The comparison of T1 corrections (for measured heights) for the 152 points, calculated for various DTMs against the ones calculated for the DTM DETAIL.

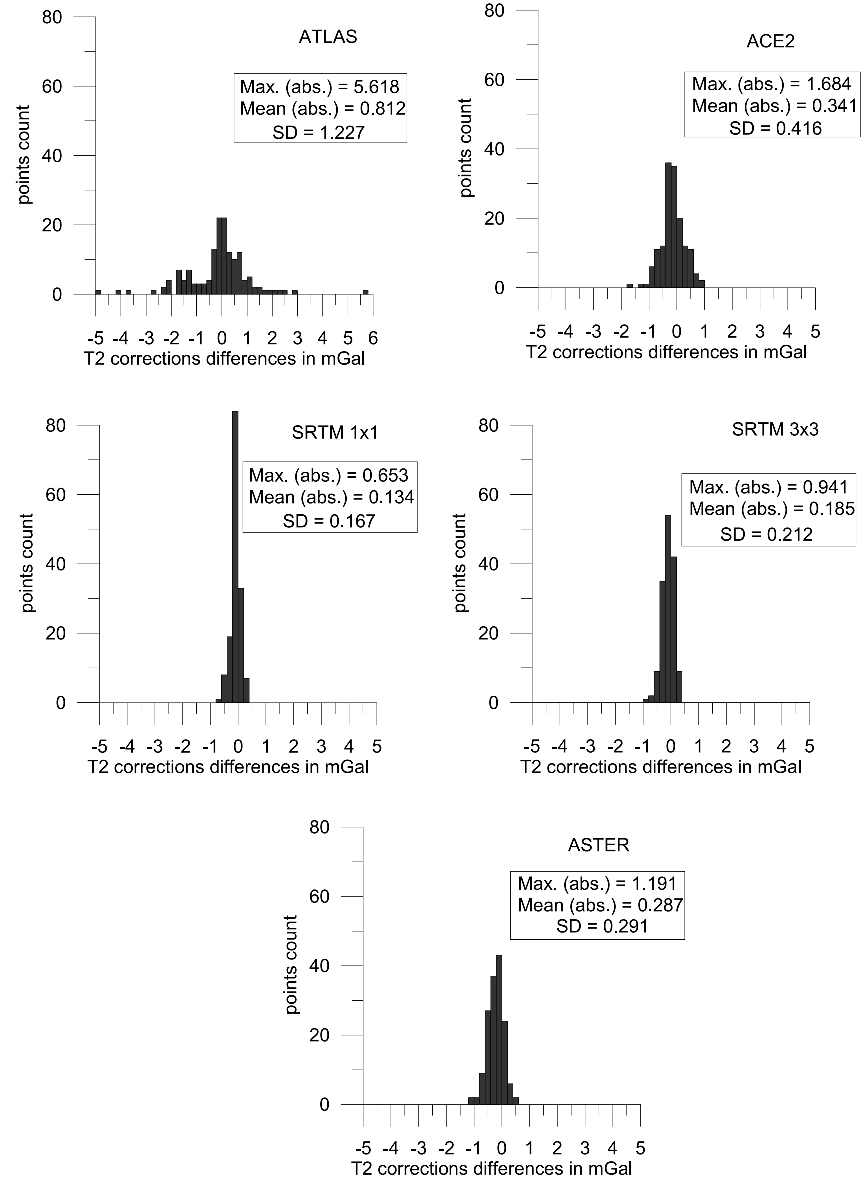

Fig. 9. The comparison of T2 corrections (for measured heights) for the 152 points, calculated for various DTMs against the ones calculated for DTM DETAIL.

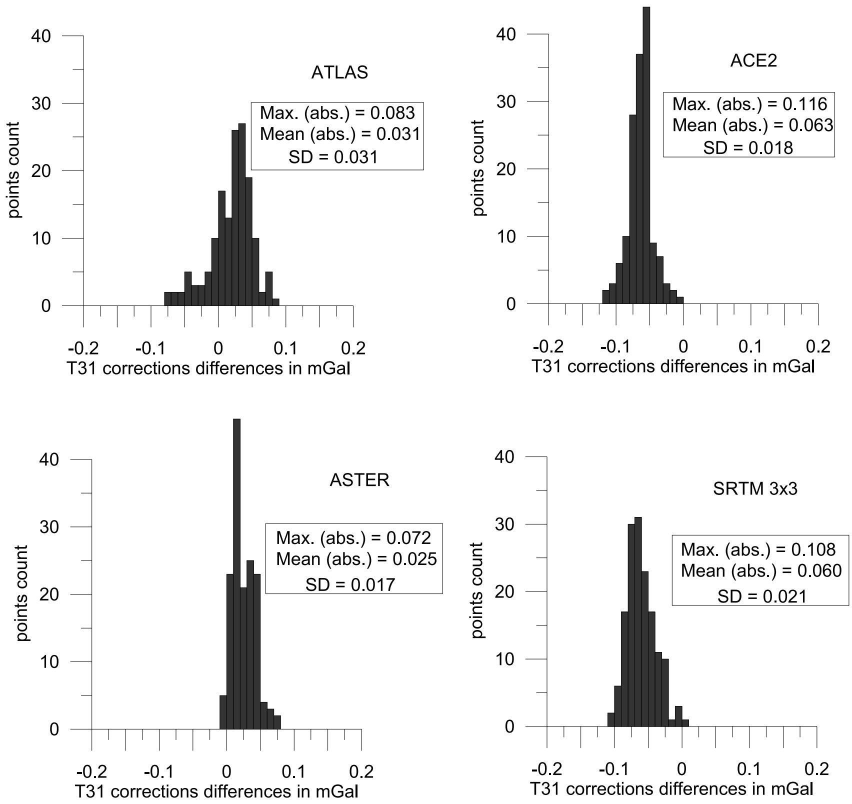

Fig. 10. The comparison of T31 corrections (for measured heights) for the 152 points, calculated for various DTMs against the ones calculated for DTM DETAIL.

2.67 g.cm^{-3}. In this test we compared both concepts of T1 calculation, i.e. for the interpolated as well as for the measured heights of calculating points. In the case of corrections T1, T2 and T31, we used the values calculated for the DTM DETAIL for a comparison with other DTMs. Since this terrain model is considerably better, we suppose that the terrain corrections calculated using this DTM will be the closest ones to their real values. In the case of T32 corrections, we used the model SRTM 3×3 for comparison, because more detailed models of Tatra Mts. (DETAIL, as well as SRTM 1×1) are of insufficient extent for the outer zones.

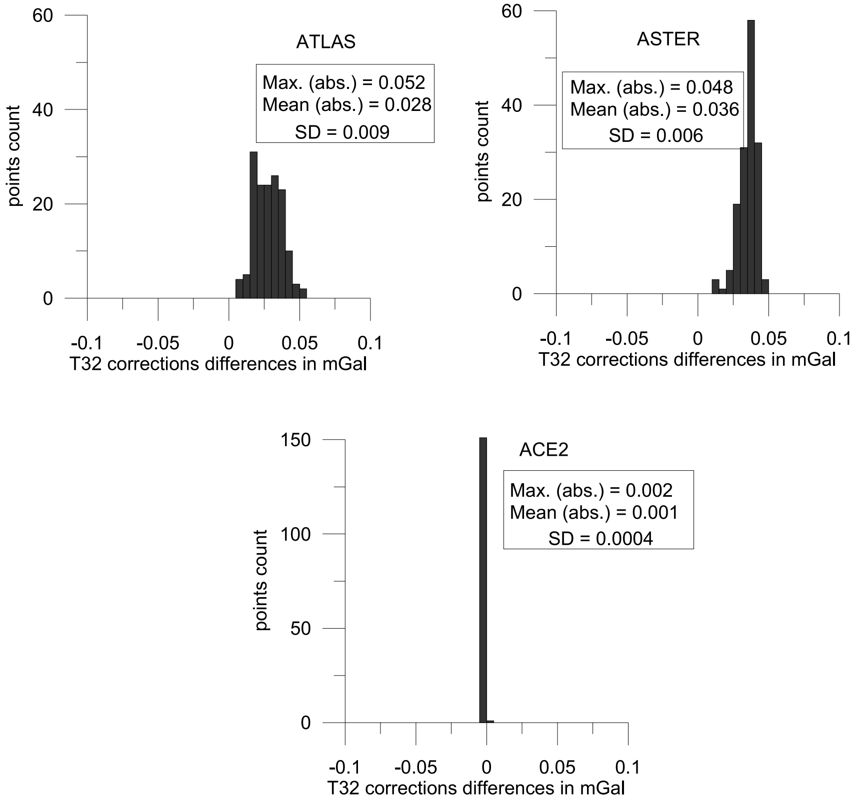

Fig. 11. The comparison of T32 corrections (for measured heights) for the 152 points, calculated for various DTMs against the ones calculated for the DTM SRTM 3×3. Note different vertical scale in the last graph.

The differences among the calculated corrections (particularly T1 and T2), in dependence on the used DTM, are much larger than the previous differences which were obtained using various programs. For instance, if we adopt the estimation of the mean error of T2 corrections according to the former Czechoslovak standard for gravity mapping *(Blížkovský et al., 1976)*, i.e. 1% of the mean value of T2 corrections, according to Table 1, from our tests it would be around 0.12 mGal. We thus see that the differences resulting from using various DTMs are much larger, e.g., the maximum difference for the model ATLAS is 5.618 mGal and the mean difference is 0.812 mGal.

Based on this we can conclude that the accuracy of the used DTM is the most important factor for the calculation of terrain corrections in such topography.

Furthermore, the question of the height of the calculating point, i.e. measured vs. interpolated height used in calculation of terrain corrections T1, is also very serious. For example, mutual differences between the T1 corrections calculated using both concepts in the case of model ATLAS can reach 15 mGal. In the case of T2 correction we get differences of approximately the same magnitude, but we consider as correct to use the measured heights for this zone. In general we do not wish to decide which concept is better. On the other hand, the results presented in Fig. 8a and 8b, i.e. where we obtained considerably smaller differences of T1 corrections calculated for interpolated heights, should be carefully interpreted. However, detailed analysis of this problem is outside the scope of this paper and we will be concerned with it in the near future.

In addition, on a subset of 29 points with the height range from 1300 to 2010 m, see Fig. 12, we tried to calculate T1 corrections using also terrain models obtained from digitized topographic maps on the scale of 1:10 000 (only in the case of these 29 out of all 152 points it was possible to get such model because of the very sharp topography impossible to digitize precisely from the maps). Such terrain models were marked as DIGIT. In Fig. 13 and 14 we present statistical results of comparison of measured vs. interpolated

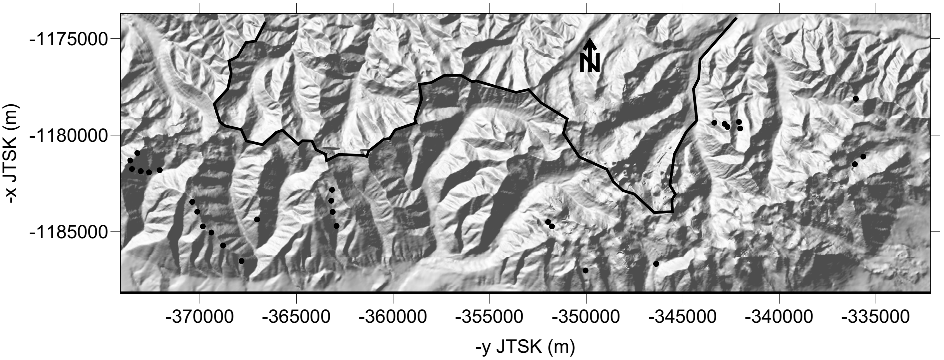

Fig. 12. Situation of the selected 29 points for whitch the T1 corrections were calculated based on the DTM DIGIT which was digitized from the topographical maps.The black line represents the Slovak-Polish border.

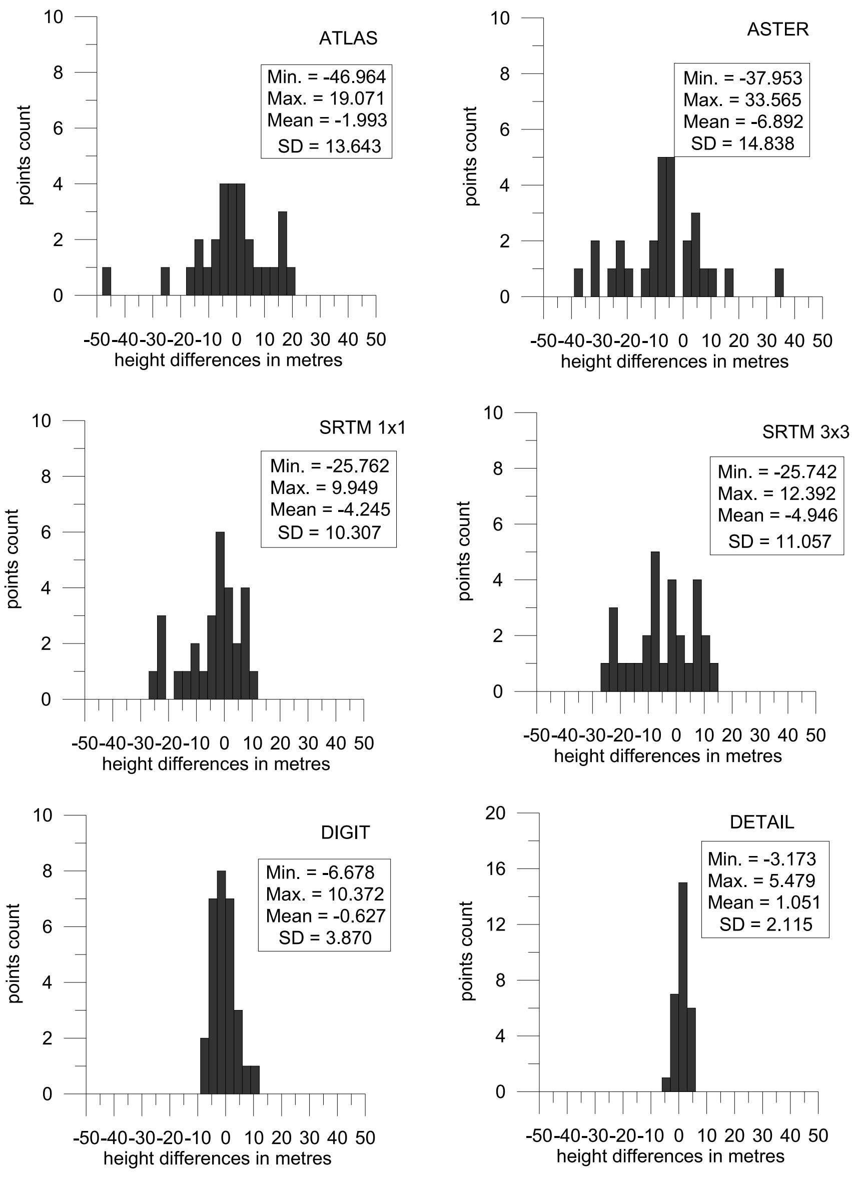

Fig. 13. The comparison of the measured and interpolated heights of the measured points from various DTMs (29 points). Note different vertical scale in the final graph.

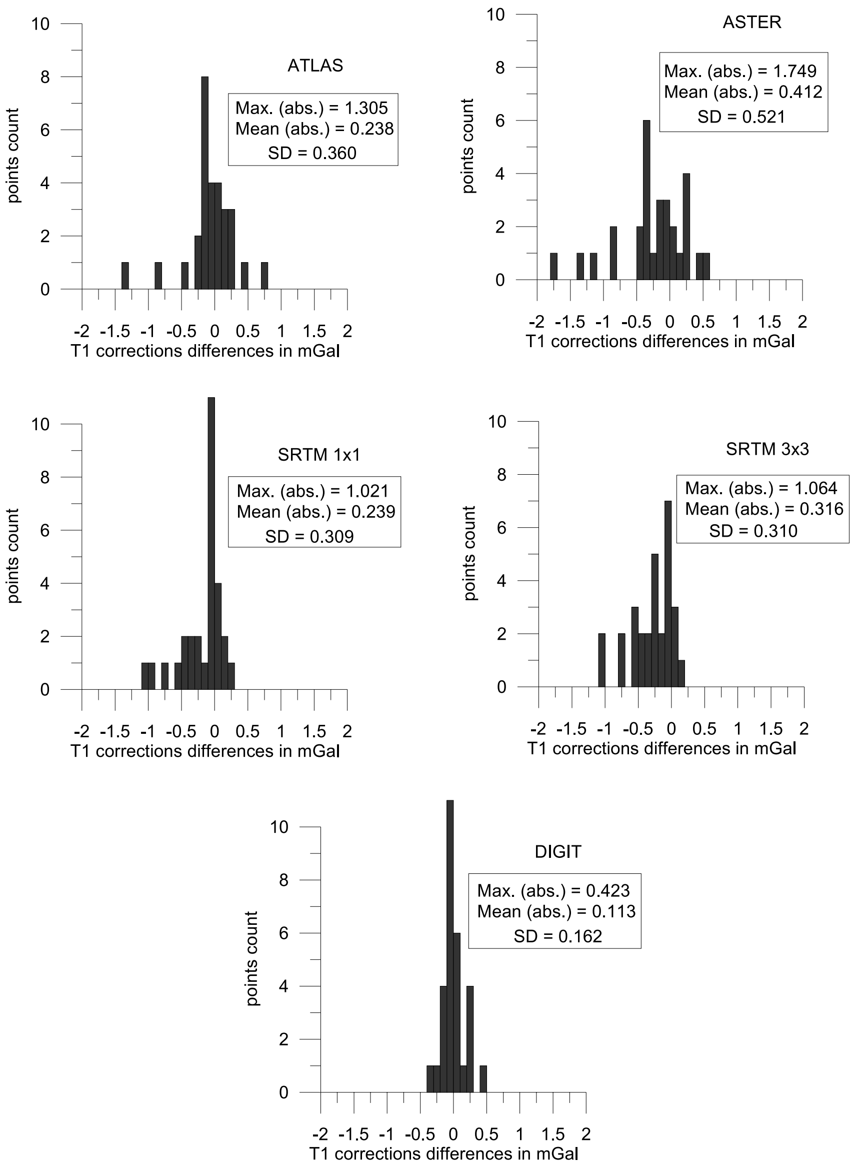

Fig. 14. The comparison of T1 corrections (for interpolated heights) for the 29 points, calculated for various DTMs against the ones calculated for the DTM DETAIL.

heights, as well as T1 corrections (computed for the density 2.67 g.cm^{-3}, using approach B, for interpolated heights) for the selected 29 points. As the reference standard for T1 corrections we again used the values T1 calculated from the terrain model DETAIL. We see that the results obtained from the digitized maps are better than those from other DTMs and they are close to those obtained from the DTM DETAIL, implying that the topographic maps on this scale are quite accurate.

Within the testing of dependency of terrain corrections on the quality of DTM, we have also paid our attention to deriving more accurate DTM using additional height data acquired in the field. As a first step, we supplemented the selected model ATLAS with measured heights of gravity points, next we tried to refine such model with information about slopes around measured points acquired using optical inclinometer. Finally, in the third step, we supplemented DTM with results of GPS measurements along the tracks during measuring days. The supplemented models in the particular steps are denoted ATLAS.1, ATLAS.2 and ATLAS.3. We evaluated the quality of these refined models (for all 152 points) on the basis of comparison between measured and interpolated height, as well as on the basis of computed terrain corrections T1. We used the terrain correction T1 calculated from the model DETAIL, i.e. from the most accurate one, as the reference standard for their comparison. The results are compiled in Fig. 15 and 16. Terrain corrections are computed for the density 2.67 g.cm^{-3} using approach B and interpolated heights of the calculating points.

One can see that the refined models are step by step more "accurate" in measured points (decreasing of differences between measured and interpolated heights is evident), however, there is no such trend in the case of the terrain corrections T1. On the contrary, the average difference in corrections is even greater. This can be explained by looking at the example of supplemented detailed topography model in Fig. 17. It is evident that the nearest surroundings of the measured point is overexposed (this situation can have also "negative" character – a deep artificial depression around the calculation point can be formed) and therefore we believe that we calculate some "overcorrections" in such case. Therefore, introducing additional information into an existing DTM in the form of measured data does not need to improve the terrain corrections. It follows from this that if we want to calculate the near terrain corrections correctly, the best way is to map the

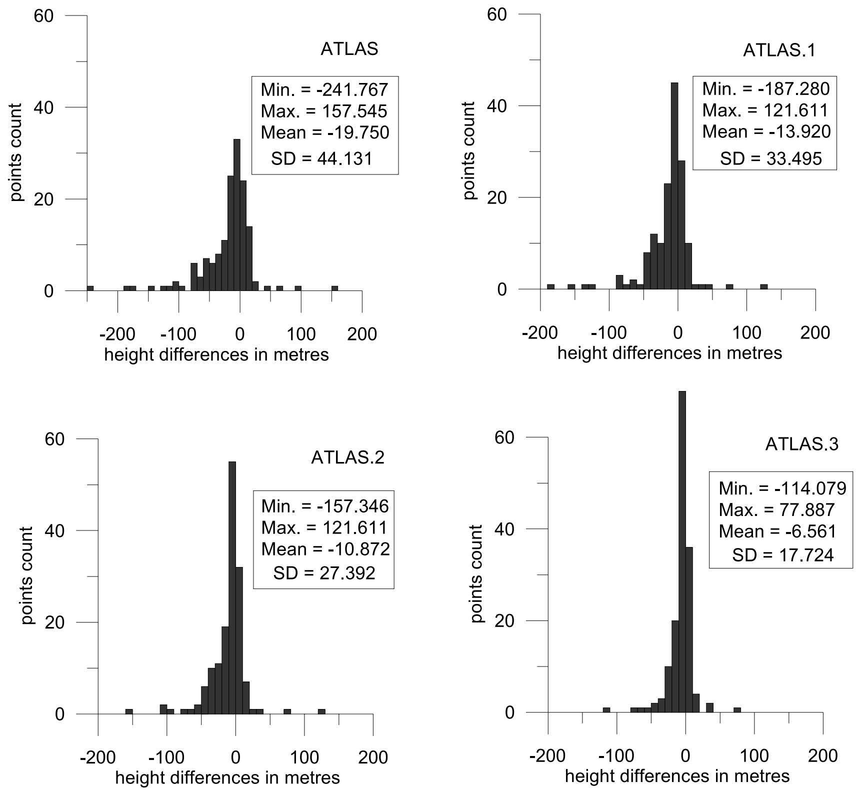

Fig. 15. The comparison of measured and interpolated heights of the measured points (152 points) from refined DTMs derived from DTM ATLAS.

close topography sufficiently in the field (e.g. using tacheometry or GPS), so that we would use exclusively this "in situ" measured data, which is of course very difficult or impossible to acquire in mountainous areas. This conclusion seems to be in accord with the recommendation of *Hinze et al. (2005, J30)* and *Steinhauser et al. (1990, 163)* to collect the near-station topographic information directly in the field either by GPS, optical, or electronic instrumentation, to a distance of about 100 m (or 50 m, respectively) from the station, and calculate the terrain correction independently of the available (detailed) DTMs, on which, on the other hand, the calculations should be based outside this near zone.

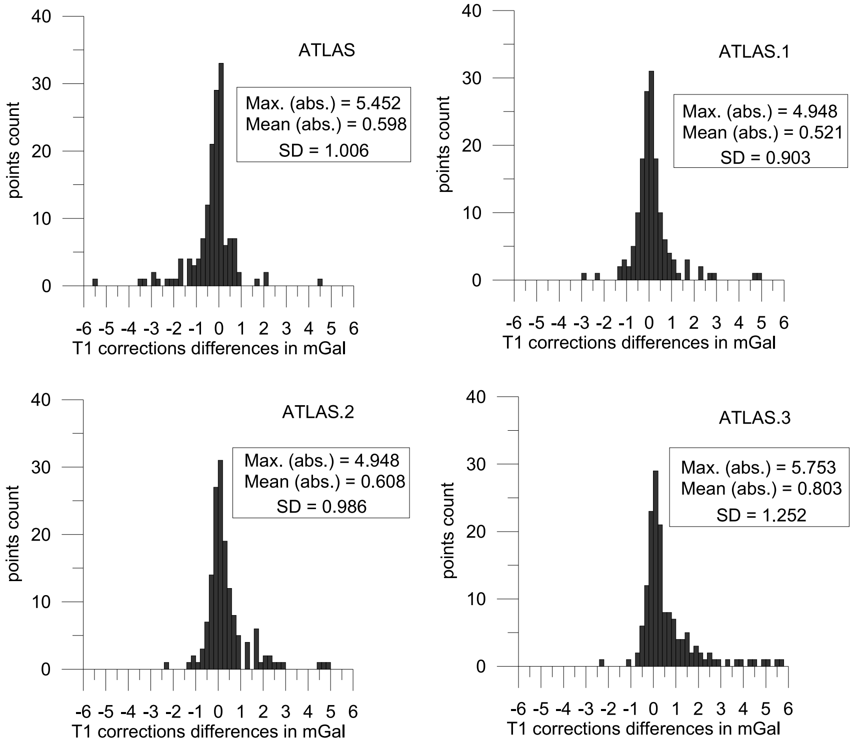

Fig. 16. The comparison of T1 corrections (for interpolated heights) for the 152 points, calculated for refined DTMs derived from DTM ATLAS against the ones calculated for the DTM DETAIL.

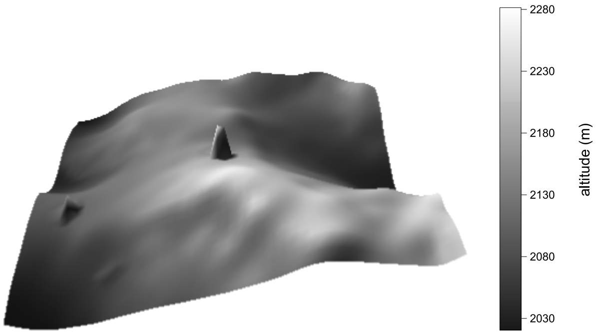

Fig. 17. Supplemented detailed model around one of the gravity points (point No. 60).

6. Conclusions

The aim of our study was to point out the errors which can be done during the calculation of terrain corrections in extreme mountainous areas like the Tatra Mountains. We have mainly focused on evaluating the errors caused by using different accessible methods of numerical calculations. Then we have analyzed the impact of inaccurate determination of the measuring point coordinates (both in horizontal and vertical directions) and finally, we have dealt with inaccuracies originated from using various digital terrain models (DTM).

The most important outcome following from our tests is that the quality of used digital terrain model is the most critical factor for the accuracy of the calculated terrain corrections in such topography. This issue is associated also with the question of whether to use measured or interpolated heights of the calculating points. The related errors can be more than 10 mGal (for the density 2.67 g.cm^{-3}). This is quite a large number. The only general recommendation is to use the most accurate of the accessible DTMs – in our study this was the so-called DTM DETAIL, which was compiled during the project CERGOP-2/Environment *(Czarnecki and Mojzeš, 2006)*.

Comparing three different programs for the numerical evaluation of terrain corrections, we have found out that the sum of absolute differences for all zones (for the density 2.67 g.cm^{-3}) was approx. 0.29 mGal. We regard this value as the current expectable maximum absolute error, which can characterize the accuracy of the calculation of terrain corrections in the Tatra Mountains area regarding the currently available software. In this error, however, any possible inaccuracy neither in the input DTM nor in the calculating point position is accounted for. It is certainly not a negligible value, but we note that the maximum value of the total terrain corrections is more than 80 mGal, so the expectable software-related error is less than 0.4 percent of this value.

Errors caused by incorrectly determined coordinates of measuring point (acquired by modern GPS techniques) are relatively small. For instance, for a considered height error of ± 0.15 m we get maximum difference 0.027 mGal (for the density 2.67 g.cm^{-3}) for T1 corrections and 0.016 mGal for T2. In the case of T31 and T32 corrections the differences are much smaller and these are negligible values in such terrain conditions. Concerning the accuracy of the horizontal position, if we consider equal error ± 0.15 m, we get very small differences in the terrain corrections (similar to those of the same height error).

Of course, we are aware that such estimations of the accuracy of terrain corrections evaluation are only of indirect character, since we compare only the relative differences in calculated terrain corrections. On the other hand, first trials have been done to compare the numerical calculations with a calibration sample – synthetically evaluated terrain correction, based on the gravitational effect of a rotational conus and/or paraboloid. For example, for a 250 m high synthetic body, the standard grid cell size of 20 metres produces differences between analytically and numerically evaluated values close to 2% of the corresponding T1 values (in the case of real data the differences between used programs were approx. 3% at mean within the T1 zone). It can be expected that a smaller grid cell size would yield more accurate results.

Acknowledgments. This work was supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and Slovak Academy of Science (projects No. VEGA 1/0461/09, 1/0882/08 and 2/0107/09) as well as by the Slovak Research and Development Agency under the contract No. APVV-0249-07. The authors thank to reviewer Ján Mikuška for his valuable comments, which significantly helped to improve the manuscript and to Zuzana Fašková for her assistance with English.

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